GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL [ ] REVISION NO. ______

Project No. A-3761 GTRI/~~GIT~~ DATE 2 / 16/84

Project Director: James M. Lefferdo ~~School~~/Lab EMSL/SE

Sponsor: First Associates, Inc.

Type Agreement: Standard Research Project Agreement

Award Period: From 2/13/84 To ~~4/8/84~~ 5/21/84 (Performance) ~~4/8/84~~ 5/21/84 (Reports)

Sponsor Amount: This Change Total to Date

Estimated: $ 16,173 $ 16,173

Funded: $ 16,173 $ 16,173

Cost Sharing Amount: $ ______ Cost Sharing No: ______

Title: "Electron Portion Control Drink Dispenser Evaluation"

ADMINISTRATIVE DATA

OCA Contact Lynn Boyd x4820

1) Sponsor Technical Contact:

2) Sponsor Admin/Contractual Matters:

Floyd I. Roberson, President
First Associates, Inc.
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Arlington, VA 22207

Defense Priority Rating: n/a

Military Security Classification: n/a
(or) Company/Industrial Proprietary: n/a

RESTRICTIONS

See Attached ______ Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with sponsor; but none proposed

COMMENTS:

*This is a subcontract under a Kentucky Fried Chicken prime.

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GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date June 29, 1984

Project No. A-3761 — ~~School~~/Lab EMSL

Includes Subproject No.(s)

Project Director(s) James M. Lefferdo — GTRI / ~~GIT~~

Sponsor First Associates, Inc.

Title Electron Portion Control Drink Dispenser Evaluation

Effective Completion Date: 5/21/84 (Performance) 5/21/84 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [x] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
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A-3761

FINAL REPORT

ELETRONIC PORTION CONTROL DRINK
DISPENSER EVALUATION

for

First Associates, Inc.
4320 Lorcom Lane
Arlington, VA 22207

Standard Contract Agreement
No. A-3761

T. B. Elfe
J. M. Lefferdo

June 1984

Energy and Materials Sciences Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

INTRODUCTION

This program was conducted by the Energy and Materials Sciences Laboratory of Georgia Tech's Engineering Experiment Station on a contract with First Associates. The program consisted of testing a drink dispensing tower with four different sets of Electronic Portion Control Units (EPC), each set manufactured by a different company.

The objective of the program was to identify performance differences between the four types of EPC's. Timing precision is of paramount interest. We were also carefully monitoring voltage and current supplied to the solenoid valves on the tower by the EPC's.

In this respect, we shall first diagram the operation of the system. Next, we shall present a step by step description of the test procedure. This will be followed by an executive summary, which discusses the purpose of each test and the results of each test. The executive summary also contains some overall conclusions. The Appendix contains results in somewhat more detail, and also discusses some of the problems encountered.

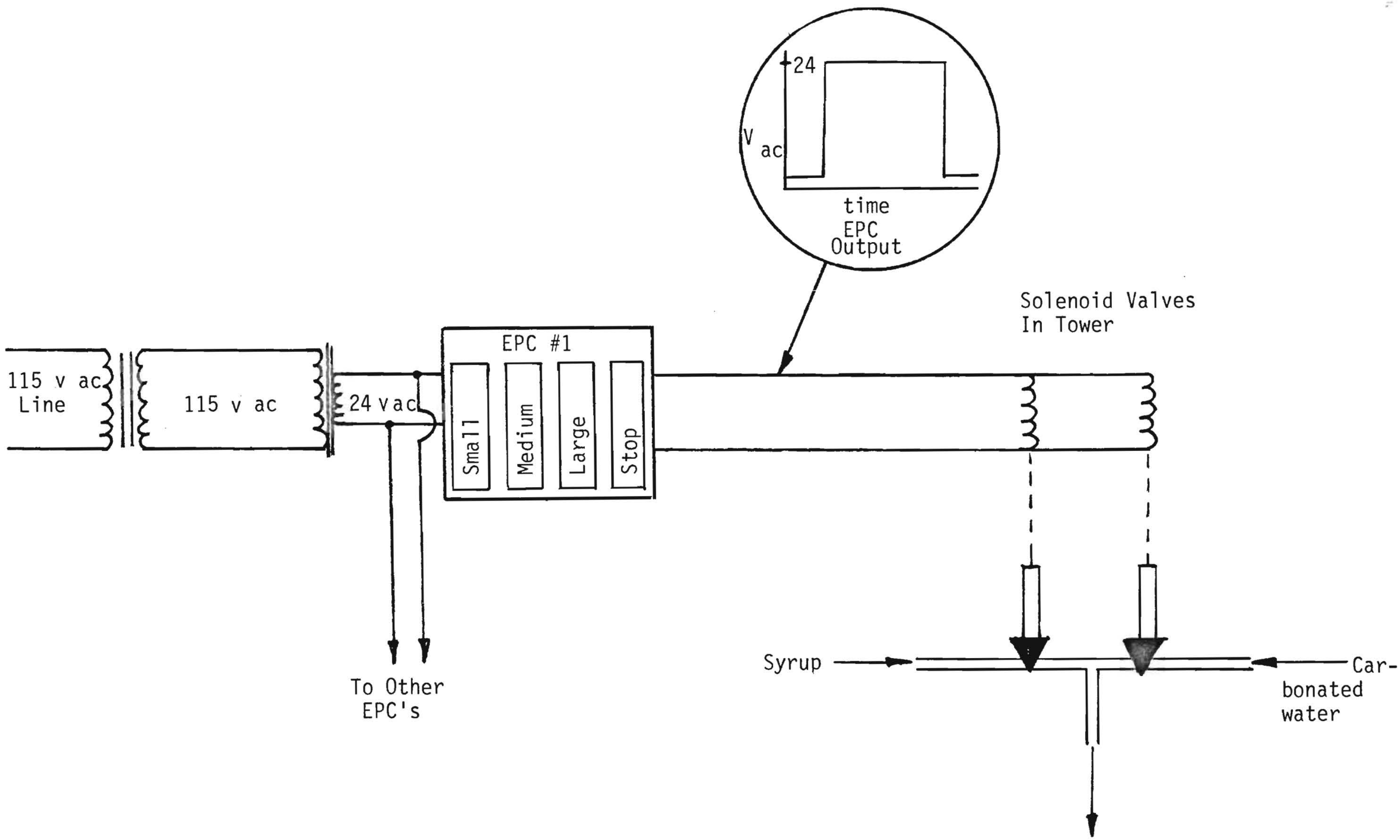

Figure 1. Schematic of Drink Dispenser.

TEST PROCEDURE

1(a) Inspect each EPC for shipping damage.

(b) Put identifying number on each valve and each EPC.

(c) Measure resistance and impedance of the 5 pairs of solenoid valves (singly and in pairs).

(d) Measure transformer secondary resistance.

2(a) Apply 24 v-ac from lab power supply to each of 10 solenoid valves and measure currents.

(b) Set resistance of 5 variable resistors so that each resistor has the same impedance as that of a pair of solenoids connected in parallel. Connect the 24 volt output of each EPC to the appropriate resistor. Apply 24 v-ac from lab power supply to the EPC under test.

i Turn potentiometer on each EPC clockwise to limit and measure time voltage is applied to dummy load.

ii Turn each potentiometer fully counter-clockwise and repeat (i).

3(a,b) Connect a constant voltage transformer between the 115 v-ac line and the tower transformer. Connect each EPC, in order, to tower. Connect syrup and CO_2 to tower. Set potentiometers so that each "small" control activation produces approximately a 7-1/2 second voltage output, a "medium" produces a 9-3/4 second output and a "large" produces a 13 second output. Record times, voltage, and drink size. Also, measure line voltage and transformer secondary current.

(c) Connect a variac between the constant voltage transformer and the tower transformer.

i Set a-c voltage 10 percent below that measured in (a,b) and repeat the measurements made in (a,b).

ii Set a-c voltage 5 percent below that measured in (a,b) and repeat the measurements made in (a,b).

iii Set a-c voltage 5 percent above that measured in (a,b) and repeat the measurements made in (a,b).

iv Set a-c voltage 10 percent above that measured in (a,b) and repeat the measurements made in (a,b).

(d) Reset line voltage to nominal. Repeat measurements made in (a,b) with drink portion sizes (small, medium, and large) varying over a range of $\pm$ 1-1/2 ounces with respect to nominal. Use approximately 1/2 ounce steps.

4 Connect EPC's to tower. Turn off syrup, CO_2 and water. Measure transformer output voltage and current, solenoid voltage, and time solenoid voltage is applied. Run the number of cycles indicated under the following conditions:

(a-j)

Drink Size & Valve	10 sec Off	5 sec Off	2 sec Off	1 sec Off	1/2 sec Off
1 small	10 (4a)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
2 small	10 (4b)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
3 small	10 (4b)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
4 small	10 (4b)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
5 small	10 (4b)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
1 medium	10 (4c)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
2 medium	10 (4c)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
3 medium	10 (4c)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
4 medium	10 (4c)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
5 medium	10 (4c)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
1 large	10 (4d)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
2 large	10 (4d)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
3 large	10 (4d)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
4 large	10 (4d)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)
5 large	10 (4d)	10 (4e)	10 (4f)	10 (4g)	90 (4h-j)

(k-u)

Valves Open	No. Of Openings	Time Between Openings (sec)	Drink Size
1,2	10	10	small
1,2	10	5	small
1,2	10	10	medium
1,2	10	5	medium
1,2	10	10	large
1,2	10	5	large
1,2,3	10	10	small
1,2,3	10	5	small
1,2,3	10	10	medium
1,2,3	10	5	medium
1,2,3	10	10	large
1,2,3	10	5	large
1,2,3,4	10	10	small
1,2,3,4	10	5	small
1,2,3,4	10	10	medium
1,2,3,4	10	5	medium
1,2,3,4	10	10	large
1,2,3,4	10	5	large
1,2,3,4,5	10	10	small
1,2,3,4,5	10	5	small
1,2,3,4,5	10	10	medium
1,2,3,4,5	10	5	medium
1,2,3,4,5	10	10	large
1,2,3,4,5	10	5	large
1,2	10	2	small
1,2	10	1	small
1,2	30	1/2	small
1,2	10	2	medium
1,2	10	1	medium
1,2	30	1/2	medium

Valves Open	No. of Openings	Time Between Openings (sec)	Drink Size
1,2	10	2	large
1,2	10	1	large
1,2	30	1/2	large
1,2,3	10	2	small
1,2,3	10	1	small
1,2,3	30	1/2	small
1,2,3	10	2	medium
1,2,3	10	1	medium
1,2,3	30	1/2	medium
1,2,3	10	2	large
1,2,3	10	1	large
1,2,3	30	1/2	large
1,2,3,4	10	2	small
1,2,3,4	10	1	small
1,2,3,4	30	1/2	small
1,2,3,4	10	2	medium
1,2,3,4	10	1	medium
1,2,3,4	30	1/2	medium
1,2,3,4	10	2	large
1,2,3,4	10	1	large
1,2,3,4	30	1/2	large
1,2,3,4,5	10	2	small
1,2,3,4,5	10	1	small
1,2,3,4,5	30	1/2	small
1,2,3,4,5	10	2	medium
1,2,3,4,5	10	1	medium
1,2,3,4,5	30	1/2	medium
1,2,3,4,5	10	2	large
1,2,3,4,5	10	1	large
1,2,3,4,5	30	1/2	large

EXECUTIVE SUMMARY

1(a) Purpose: To be certain all equipment is working properly at beginning of experiment.

Result: No shipping damage. One Tektrol EPC did not function when initially tested.

1(b) Purpose: To keep track of individual units during test.

Result: Done.

1(c) Purpose: To ascertain solenoid uniformity and to determine value to set dummy resistors.

Result: Individual resistances ranged from 17.5 to 18.2 ohms. Individual impedances ranged from 50.4 ohms to 54.9 ohms. Pair impedances ranged from 25.7 to 26.7 ohms.

1(d) Purpose: To be able to determine transformer voltage drop and power loss.

Result: Secondary resistance is 1.1 ohms.

2(a) Purpose: To determine nominal current drawn by each valve solenoid.

Result: Individual solenoid currents ranged from 437 mA to 476 mA.

2(b) Purpose: To determine ranges on time settings.

Result: All units have more than adequate range. Selmix has such a large range that adjustment tends to be more coarse.

2(c,d) Purpose: To determine effect of operating multiple EPC's and solenoid valves simultaneously.

Result: No problems per se were encountered with EPC's. The transformer which was supplied with the tower had an insufficient volt-ampere rating to operate more than 2 valves simultaneously. Operation of 3 or more valves overheated the transformer and delivered insufficient power to EPC's to operate valves reliably. A larger transformer was substituted during this test and used for subsequent tests.

3(a,b) Purpose: To set drink sizes (9, 12 and 16 oz) and determine voltage and time for each setting.

Result: Time settings of approximately 7.5, 9.75, and 13 seconds produced approximately 9, 12 and 16 ounce drinks (except sizes were different on the valve delivering Coca Cola syrup and plain water) solenoid voltages were all very nearly 24 volts. McCann and Tektrol output voltages were approximately 0.1 volt higher than Multiplex and Selmix.

3(c) Purpose: To determine effect of line voltage on valve open times.

Result: No timing errors were observed. Some of the solenoid valves operated erratically at line voltage 5 and 10 percent below nominal. This effect was more dependent on which solenoid pair was being operated than on which EPC was being used. However, we did observe more malfunctions with Multiplex and Selmix, an intermediate number with Tektrol, and fewer with McCann. Except for one isolated solenoid valve malfunction at 10 percent overvoltage when the Multiplex EPC was being tested, we encountered no problems with elevated line voltage.

3(d) Purpose: To establish drink size-time relationship.

Result: Drink size is a linear function of valve open time, with very little spread when carbonated water is mixed with syrup. There is considerable variation when tap water is used, as was the case for valve #2. The relationship between drink size and time is independent of the type of EPC being used.

4(a-d) Purpose: To determine inherent repeatability of times voltage is applied to solenoids.

Result: With 10 seconds elapsed time between cycles, most of the valve open times repeated whithin 20 milliseconds for all types and drink sizes. All McCann times were within 30 milliseconds. All Multiplex times were within 75 milliseconds, except M_3 which had one time $\sim$0.2 seconds too long. Selmix variation was less than 160 milliseconds, with the exception of L2, which jumped between 5.486 $\pm$ 0.002 seconds and 13.123 $\pm$ 0.002 seconds. All Tektrol variations were less than 90 milliseconds, except L2, which had 2 times approximately 0.35 seconds short.

4(e) Purpose: To determine effect of higher duty cycle operation on timing.

Result: 5 second off time between cycles produces no deleterious effects. McCann, Selmix, and Tektrol repeatability was not diminished at all. Multiplex had slightly higher time spread, but still shows more than adequate timing precision.

4(f) Purpose: To determine effect of still higher duty cycle operation on timing.

Result: Time between cycles is 2 seconds. Multiplex and Selmix precision is unchanged from the previous test. McCann and Tektrol may show a slight loss in precision; however, all still have more than adequate precision. Selmix #2 large shut off twice at 9.916 seconds instead of 13.1, however.

4(g) Purpose: To determine effect of still higher duty cycle on timing precision.

Result: Time between cycles is one second. No significant loss of precision on any of the EPC's was observed, as compared to the previous test.

4(h-j) Purpose: To determine the effect of almost continuous long term operation on timing precision.

Result: Each valve is operated 90 consecutive times for each drink size. Off time is 1/2 second. Data for these tests is very difficult to interpret, as we shall explain later. The following conclusions are based on what could be determined on the basis of the data we have and the results of multiple valve opening tests to be described later. If the final decision on which EPC unit to use rests on this series of tests, more effort will be required to double-check and analyze the data.

i On 10-20 occasions, McCann EPC's failed to turn off the solenoid voltage on time. This was mostly true of large drink operations and generally happened after 30 cycles.

ii Multiplex EPC's failed to turn off far less frequently than McCann, by a factor of 2 or 3. Only one of these was absolutely definite.

iii Selmix EPC's failed to turn off on two occasions - both with large drinks and after 50 cycles. One of these had two very short times after 56 cycles, but performed well until its failure to cut off on the last cycle. Jumps in timing of approximately 2 seconds were observed on 2S after 10 cycles.

iv No failure to turn off were observed on Tektrol EPC's. This is not a fair comparison, since very little Tektrol data can be retrieved at this time. All but one of the accumulated run times indicated one or more unnaturally long times.

v Generally, times were less precise under these conditions, but except for the problems noted, would not seriously impact the cost or overall quality of operation.

4(k-u) Purpose: To determine effects on timing precision when 2, 3, 4, and 5 units are operated simultaneously with off-times varying from 1/2 second to 10 seconds.

Result: In general, no differences were noted when comparison was made to the single valve data. There were a few minor exceptions.

i McCann EPC's had 3 or 4 erroneous times of 0.5 to 1 second.

ii Multiplex 4 time dropped 0.6 seconds between 1 second off runs and 1/2 second off.

iii The jump between times on SELMIX 2 switched permanently to the shorter time.

iv Tektrol 2s time increased by approximately 0.6 seconds after the 10 and 5 second off intervals.

v It appears probable that these irregularities are more a result of overheating during previous steps than simultaneous operation of multiple valves.

OVERALL CONCLUSIONS

All of the EPC types tested perform timing functions with good accuracy, except when subjected to many cycles of drink pouring with only 1/2 second off. The tower should be equipped with a transformer which has at least a 120 volt ampere rating on its secondary if extensive operation of all valves simultaneously is anticipated. Installations where line voltage is apt to be 5 percent or more low (including drop caused by pump) may have problems with solenoid valves malfunctioning.

Specific Comments on EPC's

McCann. The unit is completely potted and is the most rugged mechanically. It is the only unit which has a fuse, although the fuse does not completely protect against output short circuits. Its performance was equal or superior in all tests except the high duty cycle test, wherein it was probably the least reliable. We believe this to be a result of overheating because of insulating effects of the potting.

Multiplex. Performance was generally very good. The design is somewhat different from the other types in that the resistance which is switched in series with the solenoid is smaller for "off" than in the other units and larger for "on." This results in larger standby current and somewhat lower output voltage and current in the "on" condition. Except for being more sensitive to valve malfunctions at low line voltage, this does not appear to cause problems. Malfunctions occurred at abnormally high duty cycle, but not appreciably worse than Selmix or Tektrol.

Selmix. Performance was generally very good, except for the problem encountered with the timing jump on 2 . This may have been a manufacturing defect on one unit, or it could be a design problem. The value of the anomalous open time makes it appear that the unit is functioning as a small drink dispenser (medium, in one case) instead of large.

Tektrol. The timing function was generally very good. A large number of failures was encountered with Tektrol units which appeared to be associated with the way the leads are connected to the circuit board, sometimes making erratic contact. Out of fairness, it should be pointed out that most of the preliminary setup work was done with Tektrol EPC's, so more time was accumulated on them. Also, for rapid testing it was necessary to mount the EPC's on portable boards. This undoubtedly magnified lead connection problems as compared to having the units permanently mounted on the tower.

APPENDIX

A drink tower, equipped with 5 pairs of Dole Valves and 5 Tektrol EPC's, was consigned to Georgia Tech by the Coca Cola Company. The tower was put into operation, using carbonated water, Coca Cola syrup, and Diet Cola syrup furnished by Coca Cola through Metro Carbonation. Metro Corporation also "Brixed" the tower (i.e., adjusted the ratio of syrup to carbonated water). Valve pairs were labeled 1-5. Valves 1, 3, and 5 were connected to pour standard Coca Colas. Valve 2 was connected to pour a mixture of Coca Cola syrup and plain water, while Valve 4 was connected to pour Diet Cola.

The original plan was to have the tower equipped with Selmix EPC's. First Associates was to furnish EPC's of the other types. We contacted Coca Cola, who shipped 6 Selmix EPC's. In the ensuing time period, we received 7 each Multiplex, McCann, and Tektrol EPC's from First Associates. The Tektrol units received from First Associates were used instead of those which had been originally installed on the tower.

EPC's received from First Associates were numbered 1-7 except for the Tektrol units which were numbered 6-12 (since the original equipment Tektrols had already been numbered 1-5) the Selmix EPC's 1-6.

Tektrol EPC #11 did not function when it was installed in the test setup. There was no evidence of shipping damage. All other components arrived in good condition and functioned properly when initially tested.

The resistance of the 10 solenoid valves was measured. We also measured current in each solenoid with 24 volts applied, so that we could determine the values for appropriate dummy resistors which were to be used in place of the solenoids in succeeding steps. Results are presented in Table I.

TABLE I

SOLENOID CHARACTERISTICS

Valve Pair #		Resistance (OHMS)	Current (24 vac applied) MA	Impedance (OHMS)	Pair Impedance (OHMS)
1	a.	18.1	476	50.42	25.75
	b.	17.8	456	52.63	
2	a.	17.9	451	53.22	26.09
	b.	17.5	469	51.17	
3	a.	17.6	462	51.95	26.20
	b.	17.7	454	52.86	
4	a.	18.2	437	54.92	26.75
	b.	17.7	460	52.17	
5	a.	18.0	444	54.05	27.06
	b.	18.2	443	54.18	

Outputs of EPC circuits were connected to dummy resistors, each resistor set to simulate the pair of solenoids driven by the EPC. Each EPC drink size switch was operated 3 times. One sequence of data was taken with timing potentiometers fully clockwise (maximum pour time) and a second sequence was taken with potentiometers counter-clockwise (minimum time). Results are presented in Table II.

This test did not expose any problems with the EPC's. All appear to have more than adequate adjustment ranges and excellent time reproducibility at the ends of the ranges. The two large deviations on maximum times on Tektrol EPC's #1 and #2 look suspiciously like data recording errors.

TABLE II

TIMING RANGES

	MAXIMUM & MINIMUM TIMES*														
EPC #	1			2			3			4			5		
Drink Size	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
EPC Brand															
McCann	13.881^{2}	29.809^{6}	30.105^{26}	14.524^{1}	29.861^{2}	30.250^{53}	14.853^{4}	24.996^{45}	29.581^{37}	14.195^{6}	28.390^{26}	29.505^{5}	14.350^{4}	30.491^{11}	28.498^{3}
	0.651^{4}	1.329^{5}	1.329^{2}	0.670^{2}	1.315^{5}	1.319^{1}	0.674^{6}	1.161^{5}	$1,339^{1}$	0.661^{3}	1.306^{4}	1.318^{1}	0.672^{4}	1.331^{4}	1.317^{3}
Multiplex	21.383^{2}	21.382^{1}	21.383^{1}	18.827^{5}	19.263^{5}	20.323^{1}	21.379^{6}	21.394^{7}	21.395^{1}	21.386^{3}	21.382^{10}	19.677^{4}	21.384^{10}	21.395^{1}	21.393^{3}
	1.168^{3}	1.171^{4}	1.170^{3}	1.142^{1}	1.157^{2}	1.153^{5}	1.177^{3}	1.165^{5}	1.166^{2}	1.153^{5}	1.156^{4}	1.158^{1}	1.137^{3}	1.146^{1}	1.153^{6}
Selmix	43.269^{16}	46.652^{26}	45.826^{52}	23.580^{6}	48.687^{72}	46.638^{27}	47.065^{8}	46.853^{12}	47.154^{11}	40.585^{4}	47.413^{8}	46.410^{12}	45.268^{12}	45.551^{13}	47.505^{21}
	1.578^{1}	2.775^{5}	2.747^{2}	1.678^{2}	2.943^{3}	2.941^{4}	1.645^{3}	2.882^{4}	2.881^{5}	1.598^{4}	2.768^{2}	2.771^{2}	1.608^{4}	1.789^{2}	2.795^{1}
Tektrol	14.139^{2}	13.938^{8}	15.673^{261}	12.975^{210}	13.399^{12}	16.037^{6}	12.332^{20}	14.114^{8}	16.395^{7}	13.223^{9}	16.208^{8}	14.923^{6}	19.485^{1}	21.069^{5}	24.221^{10}
	1.686^{1}	2.795^{4}	4.549^{2}	1.611^{4}	2.656^{5}	4.321^{1}	1.576^{13}	2.606^{30}	4.284^{37}	1.624^{2}	2.702^{4}	4.320^{3}	2.492^{6}	4.156^{2}	6.691^{1}

*Superscripts are maximum deviation from average in milliseconds.

The next test consisted of measuring transformer secondary voltage and current while 0, 1, 3, and 5 EPC-Valve combinations were operated. The 5-valve tests were repeated every 10 minutes for 1 hour. In a preliminary test, we determined that the transformer which was supplied with the tower would not operate more than 2 valves reliably. We substituted a larger transformer (Stancor P8663) for all tests described herein. The transformer ratings are:

	Original	Substitute
Primary Voltage	115	115
Secondary Voltage	24	24
Secondary Current		4
Volt Amperes	50	

The data which led us to this decision is presented in Table III.

TABLE III

TRANSFORMER SECONDARY VOLTAGE AND CURRENT

	Original Transformer		Substitute Transformer	
Unit Operating	Voltage (volts)	Current (amperes)	Voltage (volts)	Current (amperes)
0	28.6	0	28.2	0
1	26.5	0.9	27.7	0.95
3	23.4	2.25	26.7	2.8
5	21.0	3.25	25.8	3.7
	(TEKTROL EPC's)			

The complete data set, taken with the larger transformer, is presented in Table IV. Valve #1 was used for all one valve tests. Valves # 1, 2, and 3, were used for all three valve tests. Minimum small drink times were used.

The most interesting aspect of these results is that the McCann, Selenix, and Tektrol EPC's draw very little current when no valves are in operation and deliver very nearly the same current to the solenoids. The Multiplex EPC's draw somewhat higher current with no solenoids operating and less current with 3 and 5 solenoids operating. If we think of the EPC performing its switching function by switching either a very large resistance (open) or a very small resistance (closed) between the 24 volt supply and the solenoids, it appears that the Multiplex EPC is designed to have an "open" series resistance of approximately 50 ohms, and a "closed" series resistance of approximately 3 ohms. This leads to incomplete switching, but should have lower switching transients.

The next test consisted of setting the EPC times to pour small, medium, and large drinks (9, 12, and 16 oz.) and to measure solenoid voltage and on time. The first series of measurements was made at nominal line voltage (115V), while subsequent measurements were made with AC input to tower $\pm$ 5 percent and $\pm$ 10 percent with respect to 115V. Results are presented in Table V.

Tests were performed wherein the EPC times were adjusted to pour a range of drink sizes. The relationship between drink size and time is a linear one with very little spread of data except in the case of Valve #2, in which tap water was used instead of carbonated water. The variation between individual valves was more significant than the variation between EPC's (which was actually undetectable). The slight departure from linearity on the large drinks from Valve #3 may have been related to the low syrup level when the test was run. Results are presented in Figure 2 a-e.

TABLE IV

TRANSFORMER SECONDARY VOLTAGE AND CURRENT

Manufacturer, Parameter		No Valves Operated*	One Valve Operated	Three Valves Operated	5 Valves Operated						
					t = 0	t = 10 min	t = 20 min	t = 30 min	t = 40 min	t = 50 min	t = 60 min
McCANN	Voltage	27.2	26.3	24.8	23.5	23.5	23.4	23.5	23.5	23.5	23.5
	Current	0.17	1.12	2.72	4.19	4.19	4.19	4.19	4.19	4.19	4.19
MULTIPLEX	Voltage	27.3	26.3	25.0	23.9	23.8	23.9	23.9	23.9	23.9	23.9
	Current	0.31	1.10	2.56	3.76	3.76	3.76	3.74	3.76	3.76	3.74
SELMIX	Voltage	27.2	26.3	24.8	23.4	23.4	23.4	23.4	23.4	23.5	23.5
	Current	0.14	1.10	2.72	4.21	4.24	4.21	4.21	4.24	4.21	4.21
TEKTROL	Voltage	27.2	26.3	24.8	23.5	23.5	23.5	23.5	23.5	23.5	23.5
	Current	0.14	1.10	2.67	4.16	4.16	4.16	4.16	4.16	4.16	4.16

*All current readings include 140 mA for operating timer relay

TABLE Va

SOLENOID VOLTAGE & OPEN TIME
TOWER VOLTAGE = 115

EPC #		1			2			3			4			5		
Drink Size		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
EPC Brand																
McCann	V	23.94	23.95	23.95	24.01	24.04	24.03	24.00	23.99	23.98	24.03	24.03	24.04	24.00	24.00	24.02
	T	7.423	9.872	13.102	7.457	9.870	13.104	9.936	10.340	13.083	7.414	9.899	13.122	7.435	9.860	12.830
Multiplex	V	23.83	23.83	23.84	23.87	23.87	23.86	23.86	23.85	23.85	23.79	23.80	23.80	23.79	23.78	23.78
	T	7.479	9.957	13.106	7.479	9.669	12.824	7.584	9.785	12.820	7.478	9.963	12.814	7.482	9.771	12.817
Selmix	V	23.70	23.70	23.70	23.76	23.77	23.77	23.76	23.76	23.76	23.84	23.85	23.85	23.73	23.74	23.74
	T	7.461	9.913	13.146	6.143	9.929	13.134	7.484	9.880	13.148	7.468	9.965	13.164	7.454	9.872	13.091
Tektrol	V	24.02	24.00	23.98	23.85	23.92	23.95	23.96	23.97	23.97	23.95	23.95	23.95	23.93	23.93	23.91
	T	7.287	9.604	12.986	6.967	9.263	12.320	7.342	9.766	12.827	7.067	9.803	12.987	7.174	9.581	12.911

TABLE Vb

SOLENOID VOLTAGE & OPEN TIME
TOWER VOLTAGE = 115 - 10%

EPC #		1			2			3			4			5		
Drink Size		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
EPC Brand																
McCann	V	21.34[1]	21.34[1]	21.44	21.50	21.50	21.50	21.47	21.47	21.47	21.54	21.54	21.54	21.46	21.46	21.46
	T	7.376	9.648	12.820	7.446	9.853	13.086	7.435	9.821	12.895	7.415	9.893	13.115	6.409	8.530	10.670
Multiplex	V	20.13	20.12	20.30	19.93	20.09	20.16	19.56[2]	19.42[2]	19.68[2]	20.51	20.41	20.55	19.28[3]	19.30[3]	19.30[3]
	T	7.480	9.957	13.525	7.535	9.977	13.646	7.518	9.778	12.820	7.477	9.965	12.824	7.511	9.903	12.839
	T	7.480	9.957	13.525	7.535	9.977	13.646	7.518	9.778	12.820	7.477	9.965	12.824	7.511	9.903	12.839
Selmix	V	21.49[3]	21.59[3]	21.50[3]	21.61	21.61	21.61	21.64	21.64	21.65	21.61	21.61	21.62	21.40[1]	21.29[3]	21.28[3]
	T	7.478	9.922	13.167	5.493	9.947	13.135	7.504	9.876	13.185	4.880	8.419	10.257	7.471	9.894	13.130
Tektrol	V	21.55	21.55[1]	21.56[1]	21.58	21.59	21.60	21.59	21.60	21.60	21.57	21.58	21.59	21.31[3]	21.29[3]	21.28[3]
	T	7.257	9.572	12.944	6.883	9.145	12.176	7.181	9.615	12.812	7.397	9.757	12.943	7.134	9.540	12.853

1. Valve malfunction 1 out of 3 times.
2. Valve malfunction 2 out of 3 times.
3. Valve malfunction 3 out of 3 times

TABLE Vc

SOLENOID VOLTAGE & OPEN TIME
TOWER VOLTAGE = 115 - 5%

EPC #		1			2			3			4			5		
Drink Size		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
EPC Brand																
McCann	V	21.83	22.80	22.79	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.81	22.49[3]	22.48[3]	22.48[3]
	T	7.418	9.876	13.107	7.450	9.853	13.097	7.444	9.861	13.068	7.407	9.895	13.082	7.176	9.476	12.800
Multiplex	V	22.82	22.84	22.81	22.78	22.77	22.79	22.81	22.82	22.82	22.73	22.73	22.73	22.64[2]	22.75[1]	22.75[1]
	T	7.488	9.970	13.582	7.533	9.975	13.677	7.671	9.961	12.818	7.549	9.965	12.817	7.569	9.959	12.820
Selmix	V	22.76[1]	22.76	22.76[1]	22.78	22.78	22.78	22.80	22.80	22.79	22.75	22.75	22.76	22.75	22.74[2]	22.75[3]
	T	7.464	9.919	13.158	5.488	9.935	13.129	7.496	9.886	13.176	4.872	8.406	10.244	7.458	9.879	13.123
Tektrol	V	22.70	22.70	22.71[1]	22.72[1]	22.73	22.73	22.72	22.68	22.72	22.66	22.66	22.66	22.71[1]	22.71[2]	22.71
	T	7.323	9.642	13.043	6.955	9.218	12.270	7.370	9.784	12.917	7.655	9.847	13.049	7.196	9.617	12.960

1. Valve malfunction 1 out of 3 times.
2. Valve malfunction 2 out of 3 times.
3. Valve malfunction 3 out of 3 times

TABLE Vd

SOLENOID VOLTAGE & OPEN TIME
TOWER VOLTAGE = 115 + 5%

EPC #		1			2			3			4			5		
Drink Size		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
EPC Brand																
McCann	V	24.83	24.83	24.83	24.85	24.85	24.86	24.78	24.80	24 84	24.79	24.78	24.80	24.83	24.84	24.84
	T	7.422	9.871	13.108	7.449	7.851	13.074	7.455	9.870	13.078	7.409	9.801	13.114	7.444	9.5894	13.103
Multiplex	V	24.91	24.91	24.91	24.87	24.87	24.88	24.93	24.93	24.93	24.88	24.87	24.87	24.87	24.87	24.87
	T	7.478	9.963	13.304	7.690	9.906	12.816	7.654	9.965	12.819	7.482	9.966	12.817	7.488	9.965	12.824
Selmix	V	24.91	24.91	24.93	24.92	24.93	24.93	24.94	24.94	24.95	24.91	24.92	24.92	24.93	24.94	24.93
	T	7.454	9.892	13.116	5.486	9.930	13.116	7.490	9.880	13.159	4.871	8.397	10.236	7.457	9.870	13.115
Tektrol	V	24.84	24.84	24.84	24.84	24.88	24.88	24.86	24.91	24.91	24.84	24.84	24.84	24.90	24.91	24.90
	T	7.290	9.580	12.950	7.254	9.580	12.777	7.326	9.736	12.812	7.567	9.790	12.975	7.165	9.560	12.891

TABLE Ve

SOLENOID VOLTAGE & OPEN TIME
TOWER VOLTAGE = 115 + 10%

EPC #		1			2			3			4			5		
Drink Size		S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
EPC Brand																
McCann	V	25.52	25.65	25.55	25.79	25.73	25.68	25.57	25.52	25.53	25.66	25.64	25.53	25.56	25.61	25.58
	T	7.422	9.871	13.113	7.447	9.854	13.096	7.443	9.868	13.075	7.392	9.890	13.121	7.441	9.888	13.147
Multiplex	V	25.76[1]	25.78	25.89	25.84	25.85	25.91	25.82	25.64	25.70	25.90	25.88	25.89	25.86	25.71	25.81
	T	7.371	9.926	13.756	7.474	10.111	14.223	7.590	9.896	13.116	7.427	9.950	13.077	7.116	9.886	13.116
Selmix	V	25.76	25.68	25.79	25.88	25.91	25.86	25.93	25.92	25.86	25.80	25.82	25.96	25.95	25.83	25.76
	T	7.443	9.889	13.102	5.464	9.901	13.080	7.462	9.851	13.130	4.843	8.369	10.202	7.436	9.849	13.083
Tektrol	V	25.77	25.76	25.66	25.77	25.78	25.78	25.60	25.58	25.66	25.88	25.88	25.84	25.96	25.92	25.93
	T	7.267	9.581	12.967	7.257	9.601	12.798	7.301	9.763	12.907	7.596	9.783	12.960	7.159	9.562	12.891

[1].Valve malfunction 1 out of 3 times.

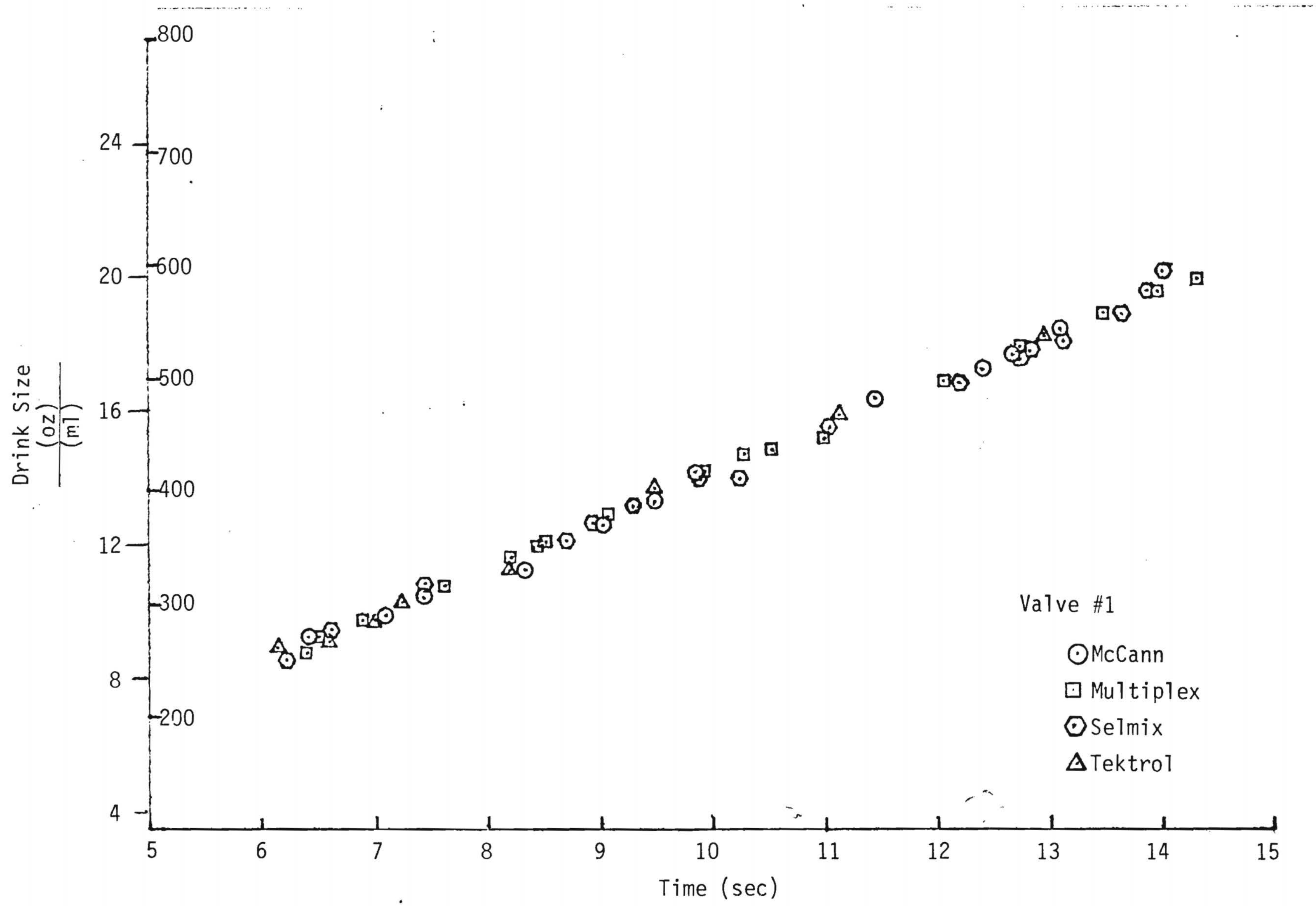

Figure 2a. Portion Size vs Time.

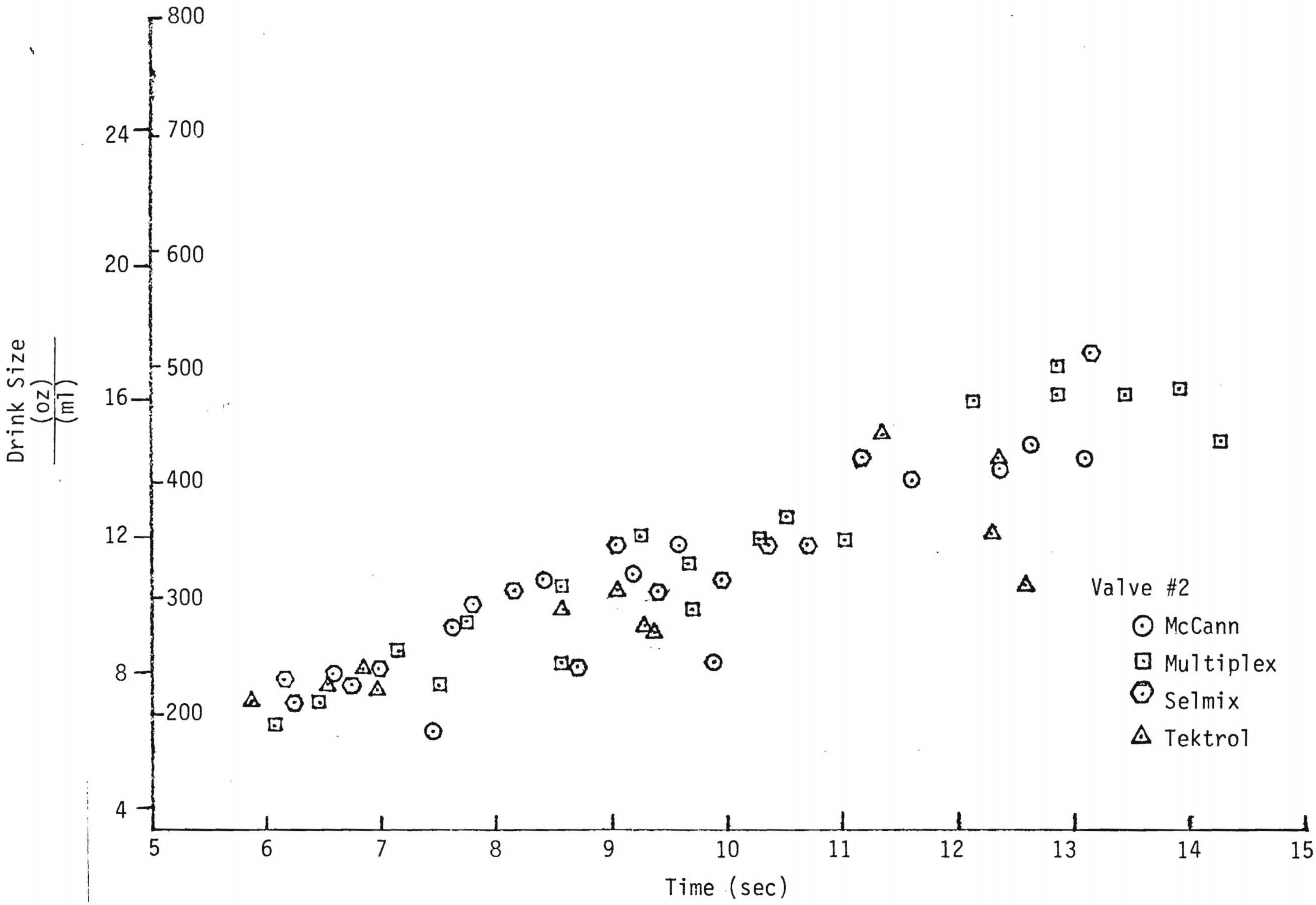

Figure 2b. Portion Size vs Time.

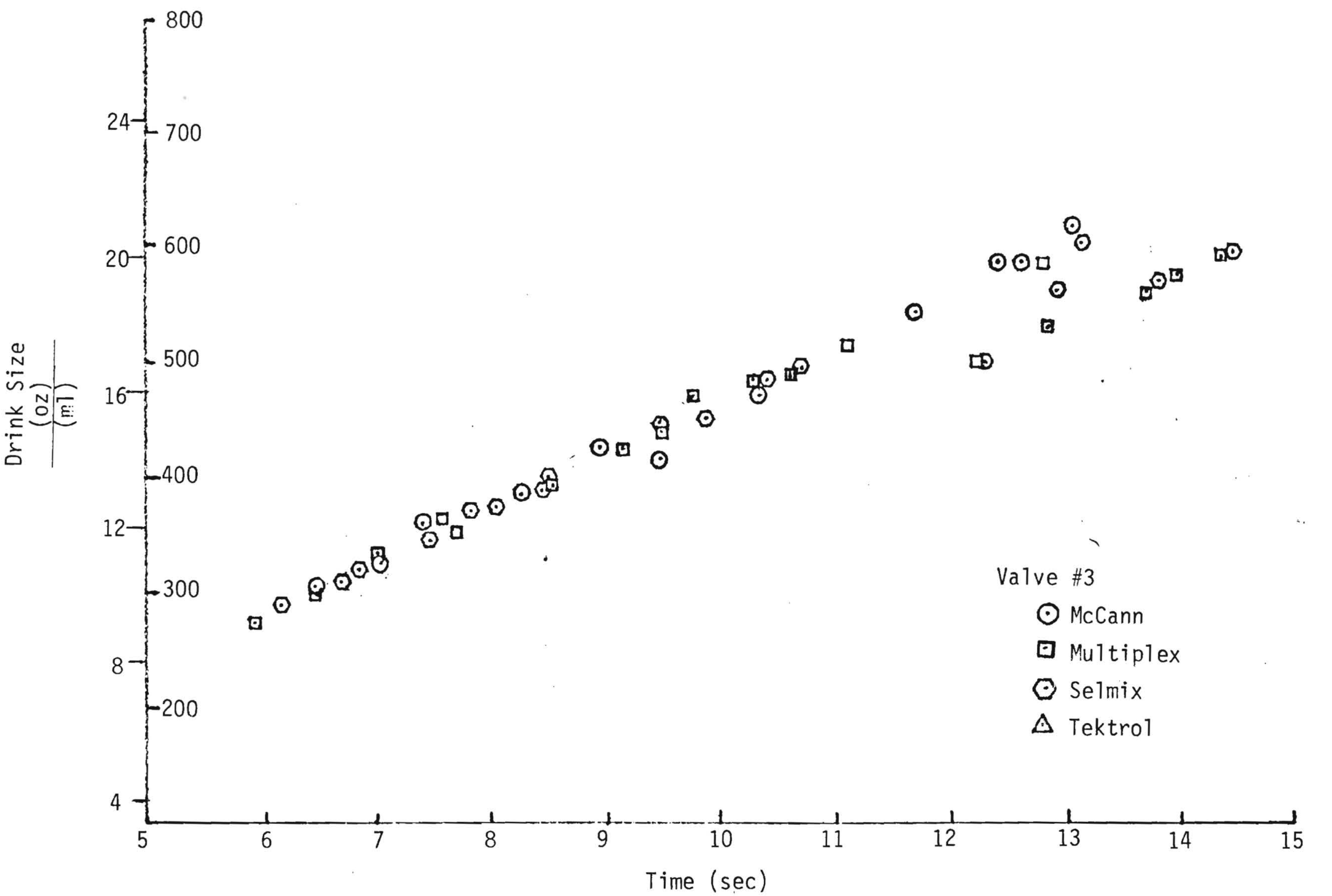

Figure 2c. Portion Size vs Time.

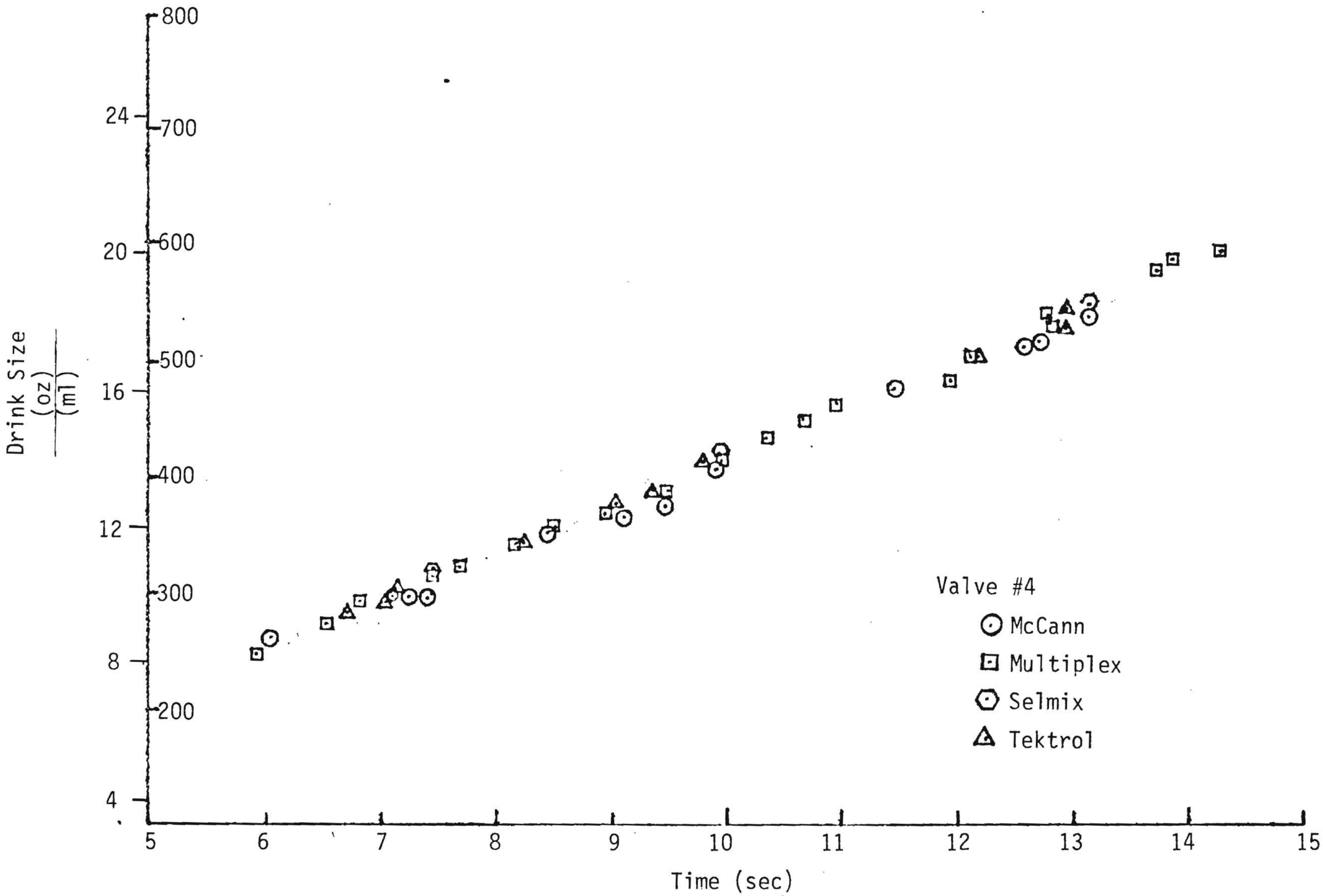

Figure 2d. Portion Size vs Time.

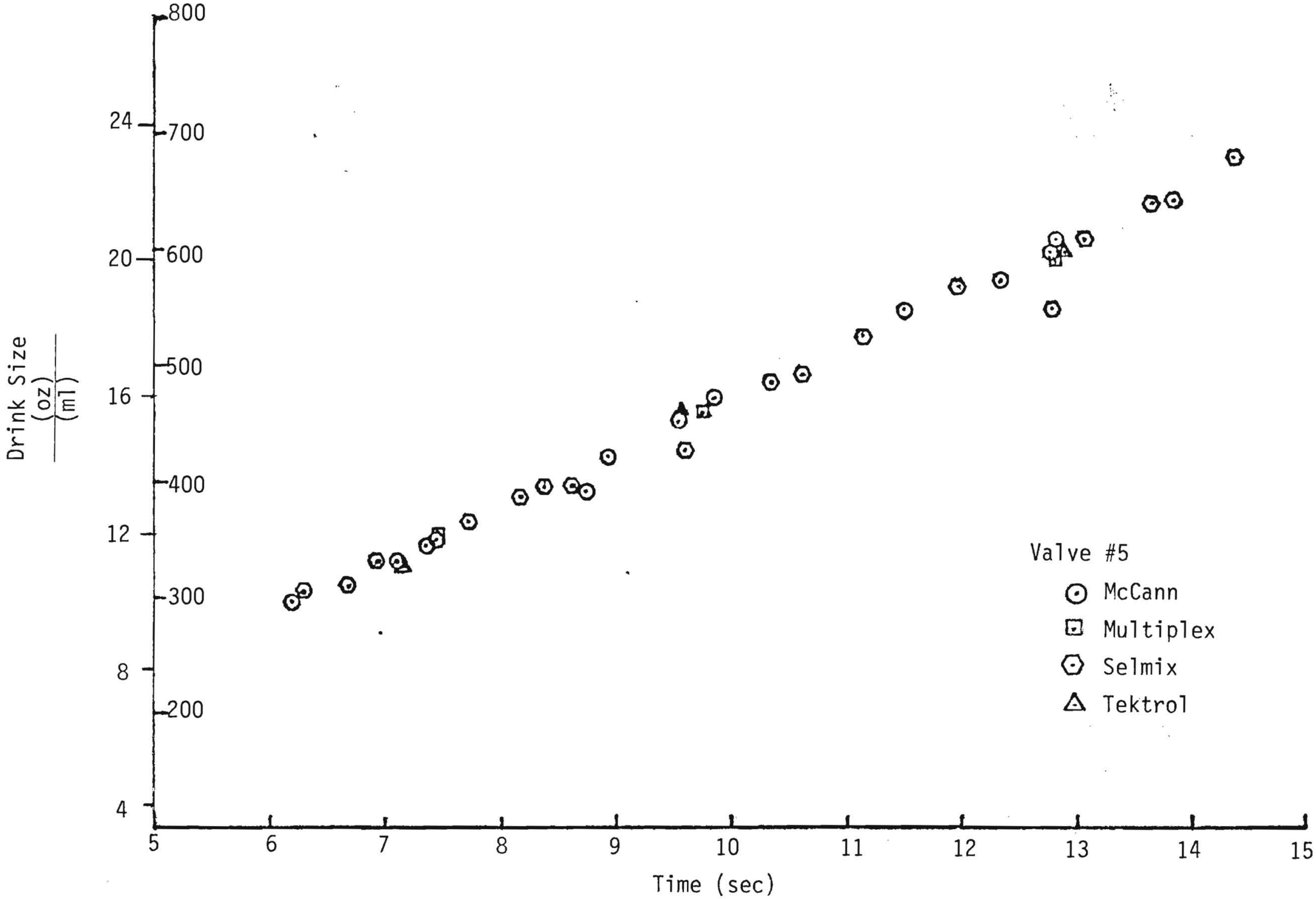

Figure 2e. Portion Size vs Time.

A large number of runs was made on individual EPC's wherein the number of cycles on each EPC was either 10 or 90 and the interval between openings was varied from 10 seconds down to 1/2 second. Some of this data was not completely reduced because of the large volume and because it appears that we have derived everything of value from it. Samples of the results are shown in Table VI. The number of data points is obviously too small to put total reliance on standard deviation. It should also be pointed out that data error rate went up as time off interval decreased. We found in general that timing precision of all units was good with off times of 1 second or longer. It appeared that all units have problems of some magnitude when off time is reduced to 1/2 second.

The simultaneous operation of 2-5 EPC-valve combinations did not introduce any significant results. Again, performance was good when off times were > 1 second. A few malfunctions occurred during the 1/2 second off runs, particularly with McCann EPC's.

TABLE 6a

McCANN EPC's

EPC#	10 sec off Average Time	10 sec off Standard Deviation	1 sec. off Average Time	1 sec. off Standard Deviation
1 small	7.426	0.002	7.420	0.003
1 medium	9.868	0.006	9.861	0.008
1 large	13.106	0.003	13.124	0.001
2 small	7.450	0.003	7.447	0.004
2 medium	9.854	0.003	9.850	0.003
2 large	13.089	0.005	13.093	0.002
3 small	7.448	0.003	7.441	0.042
3 medium	9.866	0.002	9.865	0.006
3 large	13.076	0.002	13.079	0.002
4 small	7.410	0.007	7.398	0.002
4 medium	9.898	0.002	9.899	0.003
4 large	13.118	0.002	13.124	0.012
5 small	7.427	0.006	7.431	0.004
5 medium	9.823	0.005	9.877	0.008
5 large	12.828	0.005	13.031	0.016

TABLE 6b

MULTIPLEX EPC's

EPC#	10 sec off Average Time	10 sec off Standard Deviation	1 sec. off Average Time	1 sec. off Standard Deviation
1 small	7.475	0.003	7.480	0.002
1 medium	9.961	0.002	9.969	0.004
1 large	13.142	0.015	13.223	0.012
2 small	7.479	0.004	7.475	0.020
2 medium	9.757	0.010	9.967	0.002
2 large	12.817	0.004	12.827	0.005
3 small	7.691	0.007	7.916	0.019
3 medium	9.800	0.058	9.969	0.005
3 large	12.817	0.005	12.820	0.003
4 small	7.481	0.002	7.481	0.001
4 medium	9.965	0.002	9.971	0.002
4 large	12.814	0.007	12.823	0.003
5 small	7.480	0.004	7.524	0.007
5 medium	9.770	0.014	9.970	0.004
5 large	12.817	0.005	12.826	0.06

TABLE 6c

SELMIX EPC's

EPC#	10 sec off		1 sec. off	
	Average Time	Standard Deviation	Average Time	Standard Deviation
1 small	7.451	0.003	7.454	0.002
1 medium	9.895	0.036	9.888	0.004
1 large	13.121	0.006	13.109	0.005
2 small	5.484	0.001	5.475	0.008
2 medium	9.828	0.002	9.920	0.003
2 large	10.068	3.74[1]	13.099	0.040
3 small	7.485	0.002	7.489	0.001
3 medium	9.879	0.002	9.872	0.003
3 large	13.155	0.002	13.149	0.003
4 small	4.864	0.002	4.861	0.003
4 medium	8.398	0.003	8.390	0.003
4 large	10.235	0.002	10.228	0.003
5 small	7.453	0.001	7.457	0.003
5 medium	9.870	0.002	9.866	0.002
5 large	13.100	0.003	13.091	0.001

1. Open time jumped between nominal large time (13.12) and nominal small time (5.48).

TABLE 6d

TEKTROL EPC's

EPC#	10 sec off		1 sec. off	
	Average Time	Standard Deviation	Average Time	Standard Deviation
1 small	7.281	0.004	7.295	0.005
1 medium	9.598	0.005	9.520	0.003
1 large	12.965	0.011	12.863	0.005
2 small	7.279	0.011	7.201	0.038
2 medium	9.615	0.005	9.555	0.026
2 large	12.728	0.135	12.683	0.059
3 small	7.333	0.002	7.301	0.028
3 medium	9.753	0.005	9.701	0.003
3 large	12.910	0.006	12.856	0.011
4 small	7.568	0.024	7.653	0.082
4 medium	9.781	0.003	9.813	0.006
4 large	12.960	0.006	12.988	0.010
5 small	7.156	0.004	7.180	0.003
5 medium	9.557	0.003	9.608	0.004
5 large	12.886	0.005	12.932	0.007

PROBLEMS ENCOUNTERED

Most of the problems encountered with specific pieces of equipment have already been enumerated. A few brief remarks should be made regarding problems encountered in carrying out the experiment.

Originally, we had anticipated using a chart recorder to measure voltage, current, and time. At the recommendation of the sponsor, we changed to a digital timer. We wholeheartedly concurred in this because of the expense of chart paper and the difficulty of data reduction.

The digital timer performed well for most of the experiment. There was no permanent record of times, however, and no way to rectify human errors in reading and recording the numbers. We thought this problem had been solved when we set up a video camera - recorder to have records of the digital meter readings. Unfortunately, the recorder was a very special type. It ceased to operate, and we were unable to get any reasonable promise of a repair date from the authorized service representative. We copied the tape to a more standard tape (1/2"), but the quality suffered, and many man-hours were spent retrieving the data.

The other difficulty encountered was that we decided to include a multiple position switch to sample the on-times of the EPC's being operated during the multiple operation test. A wiring error caused the failure of 1 McCann, 3 Multiplex, and 2 Tektrol EPC's.

Finally, it is apparent that we severely underestimated the data reduction task. We should have recorded data in digital format on a magnetic tape or diskette, so that it could be manipulated by computer.